EMBO *reports*

science & society

Systemic risks: a new challenge for risk management

As risk analysis and risk management get increasingly caught up in political debates, a new way of looking at and defining the risks of modern technologies becomes necessary

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A plethora of recent scandals and risk debates—such as those on bovine spongiform encephalopathy and acrylamide in the food chain, global warming and genetically modified organisms—reminds us that any human activity bears risks as well as benefits. Consequently, risk analysis and management have become increasingly important research fields to identify new, as yet unknown, risks and to devise methods for dealing with them effectively. But in light of divergent principles, values and interests, and few (if any) universally applicable moral guidelines, any general definition of risk remains elusive, thus hampering the standardization of evaluation and handling procedures. At the same time, risk management and policies would be strained if each risky activity had its own individual, tailor-made strategy of risk evaluation and management. Risk managers and policy makers therefore need a general concept for evaluating and managing risk that, on the one hand, integrates social diversity and multidisciplinary approaches and, on the other hand, allows them to institutionalize routines and standardize their practices.

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This increasing challenge for risk management goes together with the emergence of a new concept, called systemic risk (OECD, 2003). This term denotes the fact that risk to human health and the environment is embedded in a larger context of social, financial and economic risks and opportunities. Systemic risk combines natural events—partially altered and amplified by human activity, such as the emission of greenhouse gases—economic, social and technological developments with policy-driven actions both at the national and at the international level. This interdisciplinary field requires a new form of risk analysis, which geographically or functionally integrates data from various sources into one analytical approach. Consequently, systemic risk requires a holistic perspective to combine the identification of hazards, risk assessment and risk management. Investigating systemic risks therefore goes beyond the usual analysis of causes and consequences, and focuses instead on the interdependencies and relationships between various risk clusters.

To achieve this goal, systemic risk management and evaluation needs to include a variety of tasks (Renn, 1997). It needs to expand the scope of targets when risk assessment is used beyond potential damage to human life and the environment to include chronic diseases, risks to individuals' well-being and lifestyle risks, such as smoking, certain sports, drinking and others. It needs to address risk at a more aggregate and integrated level, such as studying synergistic effects of various toxins or constructing an individual's risk profile that encompasses multiple risks. Systemic risk management also needs to study and take into account variations among populations, races and individuals to obtain a more adequate picture of sensibilities with respect to people's performance, lifestyle, stress levels and external threats. On a more general level, it must integrate risk assessments into a comprehensive problem-solving exercise that encompasses economic, financial and social impacts. This would ensure that the practical value of its information can be phased into the decision-making process when required and that its inherent limitations can be compensated through additional methods of data collection and interpretation. Finally, it means developing new technologies that are more forgiving to a large range of human errors and that provide sufficient time for counteractions.

> Expanding the scope of criteria for evaluating risks is a risk in itself

Modern societies need better concepts for clarifying these new tasks of risk assessment and management and for developing substantive and procedural improvements for risk management agencies. The German Scientific Advisory Council for Global Environmental Change has developed a novel approach to risk evaluation, classification and management that could become the basis for such concepts (WBGU, 2000). There are two crucial elements of this approach: first, expanding the number of factors that should be considered when managing systemic risks and, second, integrating analytically deliberative processes into the regulatory framework. Both aspects will be discussed in the next sections.

A holistic and systemic concept of risk must expand the scope of risk assessment beyond its two classic components: extent of damage and probability of occurrence. This raises the questions 'Which other physical and social impact categories should be included to cope with the phenomenological challenges of systemic risks?' and 'How can one justify the selection?' The Council addressed these problems by organizing several expert surveys on risk criteria, including experts from the social sciences, and performed a meta-analysis of the major insights from risk assessment and perception studies. It also consulted the literature on similar approaches in other countries, including the UK, Denmark, the Netherlands and Switzerland. After a long exercise of deliberation and investigation, the Council selected several risk criteria, which are listed here: (i) Extent of damage: adverse effects measurable in natural units, such as deaths, injuries, or production losses; (ii) Probability of occurrence: estimates of the relative frequency of a discrete or continuous loss; (iii) Incertitude: an overall indicator for different uncertainty components; (iv) Ubiquity: the geographical dispersion of potential damage;

> Risk management is thus not a task for risk management agencies only, but also an imperative mandate for organizations that deal with the economic, financial, social and political ramifications of risk

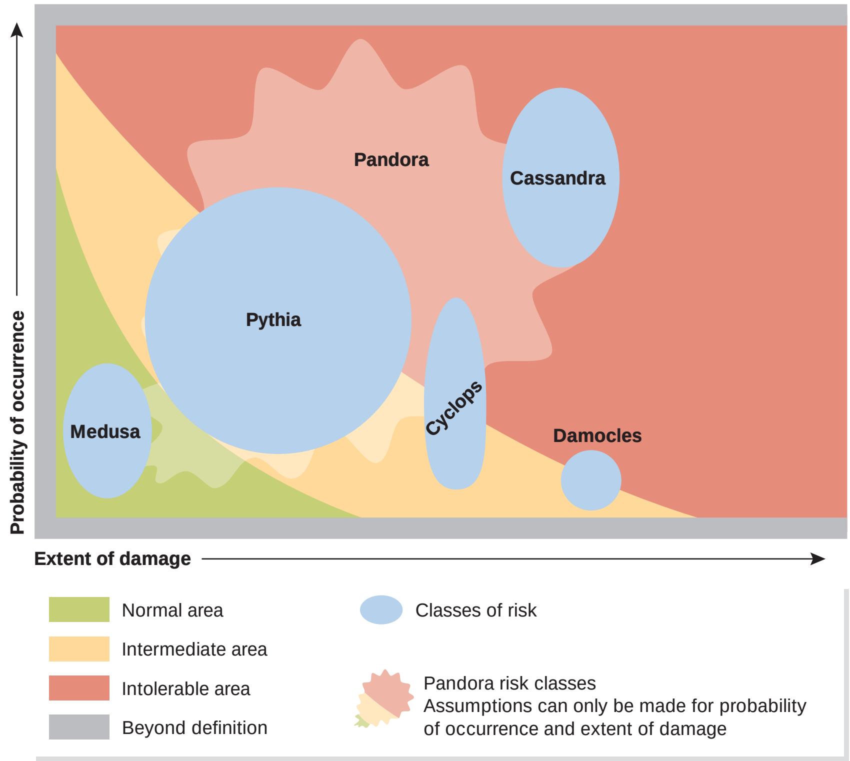


Fig 1 | Risk classes (WBGU, 2000)

(v) Persistency: the temporal extension of potential damages; (vi) Reversibility: the possibility of restoring the situation to the state before the damage occurred, for instance reforestation or water treatment; (vii) Delay effects: the latency between the initial triggering event and the actual occurrence of damage, the measure of which could be of physical, chemical or biological nature; (viii) Violation of equity: the discrepancy between those who benefit and those who bear the risks; and (ix) Potential of mobilization: potential violation of individual, social or cultural interests and values that generate social conflicts and psychological reactions by individuals or groups who feel afflicted by the consequences. These could also result from perceived inequities in the distribution of risks and benefits.

After the Council proposal had been reviewed and discussed by many experts and risk managers, the Centre of Technology Assessment in Stuttgart, Germany, refined the compound criterion 'potential of mobilization' and divided it further into four main elements (Renn & Klinke, 2001): (i) inequity and injustice associated with the distribution of risks and benefits over time, space and social status; (ii) psychological stress and discomfort associated with the risk or the risk source as measured by psychometric scales; (iii) potential for social conflict and mobilization, that is, the degree of political or public pressure on regulatory agencies; and (iv) spill-over effects that are expected when highly symbolic losses have repercussions on other fields, such as financial markets or loss of credibility in management institutions.

Expanding the scope of criteria for evaluating risks is a risk in itself. Will risk management institutions be able to handle a set of criteria further divided into sub-criteria in the time constraints under which they must operate? Is it realistic to expect risk managers to consider more formal criteria in addition to damage and probability? To address these legitimate concerns and risk managers' demand for unambiguous rules of operation, it is advisable to introduce the so-called 'traffic light' model, which evaluates risks according to the criteria mentioned above and assigns them to one of three categories: the normal area, the intermediate area and the intolerable area.

The normal area is characterized by little statistical uncertainty, low catastrophic potential, and a small overall product of probability and potential damage. It also scores low on persistency and ubiquity of consequences and high on reversibility of risk consequences. Such 'normal' risks are characterized by low complexity and are well understood by science and regulators. In this case, the classic formula 'risk equals probability multiplied by damage' is more or less identical to the 'objective' threat.

The intermediate and intolerable areas cause more problems because these risks go beyond the ordinary dimensions of risk management. The reliability of risk assessment is low, the statistical uncertainty is high, the catastrophic potential can reach alarming dimensions and there is little or no systematic knowledge about the distribution of consequences. These risks may also cause global and/or irreversible damage, which may accumulate over a long time, while mobilizing or frightening the population. It is hardly possible to come to an unequivocal conclusion about the validity of scientific evaluations of risks in these areas.

However, given the Council's criteria and numerous sub-criteria, theoretically there is a huge number of possible risk classes that would not necessarily fit into the rather simple traffic-light model. Considering the task of generating, legitimizing and communicating risk management strategies, risks with one or several extreme qualities need special attention. Consequently, similar risk phenomena are subsumed into one risk class in which they reach or exceed the same extreme qualities. For instance, risks with a damage probability of nearly one are clearly located in the intolerable area and therefore unacceptable. By the same token, if the probability of occurrence is close to zero, the event is considered harmless as long as the associated potential of damage is small. Excluded from this analysis are risks with a probability of occurrence of almost one as well as small-scale accidents with limited damage potential, even if they affect a large number of victims due to their frequency, such as car accidents.

> The dual nature of risk as a part of technological progress and as a social threat demands a dual strategy for risk management

Given these specifications and exceptions, the Council identified six risk clusters that could be placed within the traffic-light scheme (Fig 1). These clusters were illustrated with characters from Greek mythology—which were selected not just for illustrative purposes (Klinke & Renn, 1999). Looking at Greek mythology during 700–500 BC, the Council became aware that these stories reflected the transition from an economy of small subsistence farmers and hunters to organized agriculture and animal husbandry. This transition with its dramatic changes implied a new culture of anticipation and foresight; it also marked the transition from human self-reflection as an object of nature to a subject of nature. The various mythological figures thus demonstrate the complex issues associated with the new self-awareness of creating one's future rather than just being exposed to fate.

The first risk cluster was named after the legendary courtier Damocles, who envied the king, Dionysus, for his power and riches. Dionysus invited Damocles to take his place for one day. When Damocles sat at the king's place at the dinner table, he discovered that a razor-sharp sword was hanging right above him on a fine thread, to symbolize that even the king could fall victim to misfortune. The Sword of Damocles thus became a symbol for a threatening chance occurrence. The threat comes from the possibility that a fatal event could take place at any time, even if the probability is low. This cluster includes risks with large damage potentials: many technological developments and facilities, such as nuclear energy, large-scale chemical facilities and dams, have such a high disaster potential, although the probability that this potential would manifest itself as damage is extremely low (Fig 1). More formally, the prime characteristics of this risk class are a combination of low probability and high extent of damage.

The second risk cluster was named after Cyclops. The ancient Greeks tell of those mighty and bad-tempered giants who had only a single eye in the middle of their forehead. With only one eye, the dimensional perspective is lost. Regarding risks, this means that only one side of the risk equation can be ascertained while the other remains uncertain. For risks belonging to the Cyclops class, the probability of occurrence is largely uncertain, whereas the disaster potential is high and relatively well known (Fig 1). This category includes a number of natural hazards, such as earthquakes, volcanic eruptions, floods and El Niño, for which there is limited knowledge about their causes. In other cases, this criterion is uncertain because human behaviour influences the probability of occurrence. The spread of HIV/AIDS and other infectious diseases, the possibility that nuclear early warning systems could trigger a false alarm and the use of weapons of mass destruction therefore belong to this risk class.

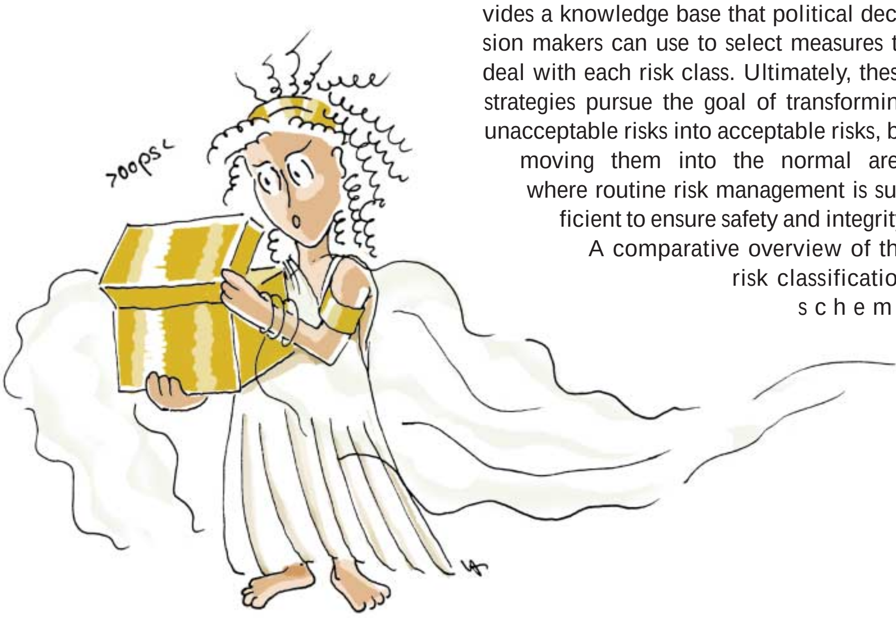
The mythological character Pythia names the third risk cluster. In cases of uncertainty and doubt, the ancient Greeks usually consulted one of their oracles. The most famous among them was the Oracle of Delphi with its blind seeress Pythia who intoxicated herself with volcanic gases to gain visions about the future. However, Pythia's prophecies were always highly ambiguous. Transferred to risk evaluation, this means the overall incertitude is high because both the probability of occurrence and the extent of damage are uncertain (Fig 1). This class includes risks associated with the possibility of sudden, nonlinear climatic changes, such as self-reinforcing global warming or the instability of the West Antarctic ice sheet, with far more disastrous consequences than those of gradual climate change. It further includes technological risks in certain applications of genetic engineering in agriculture and food production, for which neither the maximum amount of damage nor the probability of certain damaging events can be estimated at the present time.

The fourth risk cluster is named after the story of Pandora's box. After Prometheus brought fire to mankind, the gods wanted to punish humans for using something that they believed belonged only to them. They created beautiful and curious Pandora and offered her to Prometheus's brother Epimetheus. As a wedding gift, they gave her a box but warned her never to open it. However, curious Pandora did exactly that and evil, pain, pestilence and other horrors flew from the box, and caused irreversible, persistent and wide-ranging damage. Man now knew suffering. A number of human interventions in the environment also cause wide-ranging, persistent and irreversible changes without a clear attribution to specific damages—at least during the time of diffusion. Often these damages are discovered only after the ubiquitous spread has occurred. A good example of this effect refers to chlorofluorocarbons, which were developed and applied because of their apparently low impact on human health and the environment. However, they were later found to be causing the gradual destruction of the ozone layer. One could also subsume in this category the effects of persistent chemicals that might influence reproductive functions, such as endocrine disruptors.

Cassandra, a Trojan seeress, correctly predicted the Greeks' victory, but her compatriots did not take her seriously. The fifth risk class, Cassandra, dwells on this paradox: the probability of occurrence as well as the extent of damage are high and relatively well known, but because there is a considerable delay between the triggering event and the occurrence of damage, such risks are ignored or downplayed. Anthropogenic climate change and the loss of biological diversity are examples of such risk phenomena, in which damage occurs with high probability, but where the delayed effect leads to a situation in which no one is willing to acknowledge the threat. Of course, risks of this type are only interesting if the potential of damage and the probability of occurrence are relatively high. That is why this class is located in the 'intolerable' red area (Fig 1).

The sixth and final class takes the name of the creature Medusa. The mythological world of ancient Greece was full of dangers and monsters that threatened people, heroes and even the gods. Medusa, one of the Gorgon sisters, was a particularly terrible threat. The Greeks feared her not only because of the poisonous snakes on her head but also because anyone who looked directly into her face turned to stone. Much like the Gorgons, some new technological developments spread fear among modern people, such as non-ionizing radiation. Such phenomena have a high potential for psychological distress and social mobilization that make them frightening or unwelcome, although they are rarely assessed as a threat. This risk class is only of interest if there is a particularly large gap between the layperson's risk perception and expert risk analysis. A typical example is the case of electromagnetic fields, for which most experts could prove no epidemiologically or toxicologically significant adverse effects (Wiedemann *et al*, 2000). Exposure, however, is widespread and many people feel involuntarily affected.

The ultimate aim of classifying risks is to draft feasible and effective strategies for risk management and to provide measures for policies on different political levels. This characterization provides a knowledge base that political decision makers can use to select measures to deal with each risk class. Ultimately, these strategies pursue the goal of transforming unacceptable risks into acceptable risks, by moving them into the normal area where routine risk management is sufficient to ensure safety and integrity. A comparative overview of the risk classification scheme



(Table 1) indicates that one can distinguish three main categories of risk management, namely science-based, precautionary and discursive strategies. Damocles and Cyclops require mainly science-based management strategies, Pythia and Pandora demand the application of the precautionary principle, and the risk classes Cassandra and Medusa require discursive strategies for building consciousness, trust and credibility.

These three strategies relate to the main challenges in risk management: complexity, uncertainty and ambiguity. Complexity refers to the difficult task of identifying and quantifying causal links between a multitude of potential risks and specific adverse effects (WBGU, 2000). This difficulty is due to interactive effects, such as synergism and antagonism, long delay periods between cause and effect, individual variations, intervening variables and others. Uncertainty is different from complexity. It is obvious that probabilities of risk represent only an approximation of predicting uncertain events. It seems prudent to include additional uncertainty components in one's risk management procedure. Although there is no established classification of uncertainty in the literature (van Asselt, 2000; Renn & Klinke, 2001), these elements all have one feature in common: uncertainty reduces the strength of confidence in the estimated cause and effect chain. If uncertainty has an important role, in particular as indeterminacy or lack of knowledge, a risk-based management approach becomes counterproductive. Judging the relative severity of risks on the basis of uncertain parameters does not make much sense. Under these circumstances, the precautionary principle is required. This has been the basis for much of European environmental and health protection legislation and regulation (Bennet, 2000; Klinke & Renn, 2001). The last term is ambiguity, or ambivalence. This term denotes the variability of legitimate interpretations based on identical observations or data assessments. Most of the scientific disputes in the fields of risk analysis and management do not refer to differences in methodology, measurements or dose–response functions, but to the question of what all this means for human health and environmental protection. Again, high complexity and uncertainty favour the emergence of ambiguity, but there are also quite a few simple and almost certain risks that can cause controversy and thus ambiguity. A good example for a highly ambiguous risk is the use of stem cells for research. The question of whether this violates moral standards is driving the debate and much less important is the issue of complexity or uncertainty.

How can one deal with complexity, uncertainty and ambiguity in risk management? To cope with all three challenges, deliberative methods should have a major role. First, resolving complexity requires deliberation among experts, which can be framed as 'epistemological discourse' (Renn, 2004). Experts—not necessarily scientists—argue over factual assessment with respect to the criteria that the Council proposed. The objective of such a discourse is to find the most adequate description or explanation of a phenomenon; for example, which physical impacts are to be expected from the emission of specific substances. The more complex, multidisciplinary and uncertain a phenomenon appears to be, the more necessary is such a communicative exchange of arguments among experts. The goal is to achieve a homogeneous and consistent definition of the phenomenon in question as well as a clarification of dissenting views to produce a profile of the risk on the selected criteria. Epistemological discourses are well suited for risks that fall into the category of Damocles and Cyclops.

If risks are associated with high uncertainty, scientific input is only the first step in a more complex evaluation procedure. It is still essential to compile the relevant data and the various arguments of the different science camps, but it also requires collecting information about the types of uncertainties. This type of discourse requires the inclusion of stakeholders and public interest groups. The objective is to find the right balance between too little and too much precaution. There is no scientific answer to this question and even economic balancing procedures are of limited value, because the stakes are uncertain. This type of deliberation could be framed as 'reflective discourse'. It deals with the clarification of knowledge and the assessment of trade-offs between the extremes of over- and underprotection. Reflective discourses are mainly appropriate as a means to decide on risk-averse or risk-prone approaches to innovations and provide answers to the question of how much uncertainty one is willing to accept for some future opportunity—Is taking the risk worth the potential benefit? Reflective discourses are best suited to deal with risks that fall in the category of Pythia and Pandora.

The last type of deliberation, which can be framed as 'participatory discourse', is focused on resolving ambiguities and differences about values. Established procedures of legal decision making, and also novel

Table 1 | Overview of the management strategies

Management	Risk class	Extent of damage	Probability of occurrence	Strategies for action
Science-based	Damocles Cyclops	High High	Low Uncertain	•Reducing disaster potential •Ascertaining probability •Increasing resilience •Preventing surprises •Emergency management
Precautionary	Pythia Pandora	Uncertain Uncertain	Uncertain Uncertain	•Implementing precautionary principle •Developing substitutes •Improving knowledge •Reduction and containment •Emergency management
Discursive	Cassandra Medusa	High Low	High Low	•Consciousness building •Confidence building •Public participation •Risk communication •Contingency management

procedures, such as mediation and direct participation by citizens, belong to this category. Participatory discourses are mainly appropriate as a means to search for solutions that are compatible with the interests and values of the people affected and to resolve conflicts among them. This discourse involves weighting the criteria and interpreting the results. Issues of fairness and environmental justice, visions of future technological developments and societal change, and preferences for desirable lifestyles and community life have a major role in these debates. Participatory discourses are best suited for dealing with risks falling into the categories of Medusa and Cassandra.

The central question for policy makers is: 'What are the suitable approaches and instruments and adequate risk-assessment practices for understanding the impacts of risks and for assessing and evaluating their contribution to health-related, environmental, financial and political risks—and, of course, opportunities?' This also concerns strategic policies as they relate to economic development and governance needs. One of the most challenging topics here is the 'interpenetration' of physical, environmental, economic and social manifestations of risks. Risk management is thus not a task for risk management agencies only, but also an imperative mandate for organizations that deal with the economic, financial, social and political ramifications of risk.

The long and arduous debates about risk and risk assessment have shown that it is no longer sufficient simply to look into the probability distribution of potential losses associated with a risk source. To establish a framework for good governance, a more stringent and logically well-structured decision-making process is required. Risk managers need new principles and strategies that are globally applicable to managing systemic risks. Good governance in turn needs to rest on three components: knowledge, legally prescribed procedures and social values. It has to reflect specific functions, from early warning to new assessment and management tools, which will lead to improved methods of effective risk communication and participation.

The promises of new developments and technological breakthroughs need to be balanced against the potential evils that the opening of Pandora's box may entail. This balance is not easy to find as opportunities and risks emerge in a cloud of uncertainty and ambiguity. The dual nature of risk as a part of technological progress and as a social threat demands a dual strategy for risk management. It will be one of the most challenging tasks of the risk community to investigate and propose more effective, efficient and reliable methods of risk assessment and risk management, while ensuring the path towards new innovations and technical breakthroughs.

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doi:10.1038/sj.embor.7400227